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# A COMPARISON OF COMPUTER-BASED TRAINING AND CONVENTIONAL CLASSROOM TRAINING FOR TECHNICAL INSTRUCTION

A Thesis

Presented in Partial Fulfillment of the Requirements for the degree of Master of Science in the Graduate School of The Ohio State University

by

David Stanley Spotts, B.S., M.S.

* * * * *

The Ohio State University

1992

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# VITA

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## FIELDS OF STUDY

Major Field: Industrial and Systems Engineering

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# INTRODUCTION

The purpose of this thesis is to determine if there is a difference in the quality of instruction between classroom training and that of computer-based training (CBT) in a technical environment. Many applications for CBT have been found in the educational systems of the United States and Europe. At the present time, however, CBT is most frequently used as a supplement to conventional classroom instruction or as remedial instruction.[1]

This thesis explores the use of CBT as a primary means of specifically teaching technical personnel the fundamentals of industrial pneumatics. The project was conducted at an automotive manufacturer located in central Ohio. Pneumatics was chosen as a basic course that would have broad applicability to technical personnel throughout that organization.

With the advent of new technologies and the consumers' demand for quality, it is imperative for industry to have the trained personnel capable of running the equipment correctly and efficiently. Because this training must be given, the underlying question becomes that of: "How is the training going to be delivered?"

CBT offers a number of possible benefits including reduced instructional and administrative costs and greater versatility. However, there is a great reluctance to use CBT extensively. The traditional classroom teaching approach is so imbedded in our culture that it is difficult to readily accept alternative methods. It is evident more research is required to determine the effectiveness of computer-based training.

# CHAPTER I

# PNEUMATICS

## PNEUMATICS OVERVIEW

As the course being used for this experiment deals with pneumatics power systems, a short description of this field would be appropriate. The study of pneumatics is a subset of the larger field of fluid power. A fluid is defined as any liquid or gas.[2] Fluids are distinguished from solids by the fact that solids possess both rigidity and elasticity, whereas fluids possess only elasticity.[3] The fluid medium used in a pneumatic power system is compressed air.

The purpose of any fluid power system is to transmit power from one point to another.[4] In a pneumatic circuit this is accomplished in a standard process. Mechanical power, in the form of an air compressor, is used to compress the air to a pressure that is typically between 100 and 150 pounds per square inch (PSI).[4] This pressurized air is then stored in a tank until needed.

Once the compressed air has been released from the tank, it flows through tubing or piping until it approaches the machinery on which it is to be used. Here, the air is conditioned. This conditioning typically includes

regulating the air pressure to a suitable level, filtering unwanted particles and water from the air, and inserting a light oil into the air stream to lubricate downstream components such as valves and cylinders.

After the air has been conditioned, its direction and rate of flow are controlled by a variety of valves. These valves route the pressurized air to its final destination, a mechanical actuator.

Mechanical actuators are the means by which the pneumatic power is converted back into mechanical energy. Air cylinders are typically used to convert the power into linear motion while rotary actuators or motors are used to transform the power into rotary motion. Both types of actuators are used extensively throughout industry.

Fluid power systems (hydraulic and pneumatic) possess some inherent advantages over other methods of power transmission. One such advantage is the flexibility of the fluid system. Fluid power can travel anywhere tubing and piping are fitted. This makes its use extremely adaptable and flexible.

Another distinct advantage of fluid systems is the simplicity of their design. These systems generally contain fewer moving parts than comparable mechanical or electrical power systems. Therefore, fluid systems are easier to maintain and operate.[4]

Other advantages include relatively quiet operations, ease of speed control and an extremely large range of operations.[4] These advantages, coupled with an expanding automation market, create a growing number of applications and uses of fluid power systems in industry today.

PNEUMATICS COURSE OUTLINE

The course used for the comparison between classroom instruction and CBT is titled Basic Pneumatics. The purpose of this course is to impart an understanding of pneumatic fundamentals to plant personnel who have little or no knowledge of the subject. To achieve this objective, the course is divided into six chapters. This chapter breakdown is listed in Figure 1.

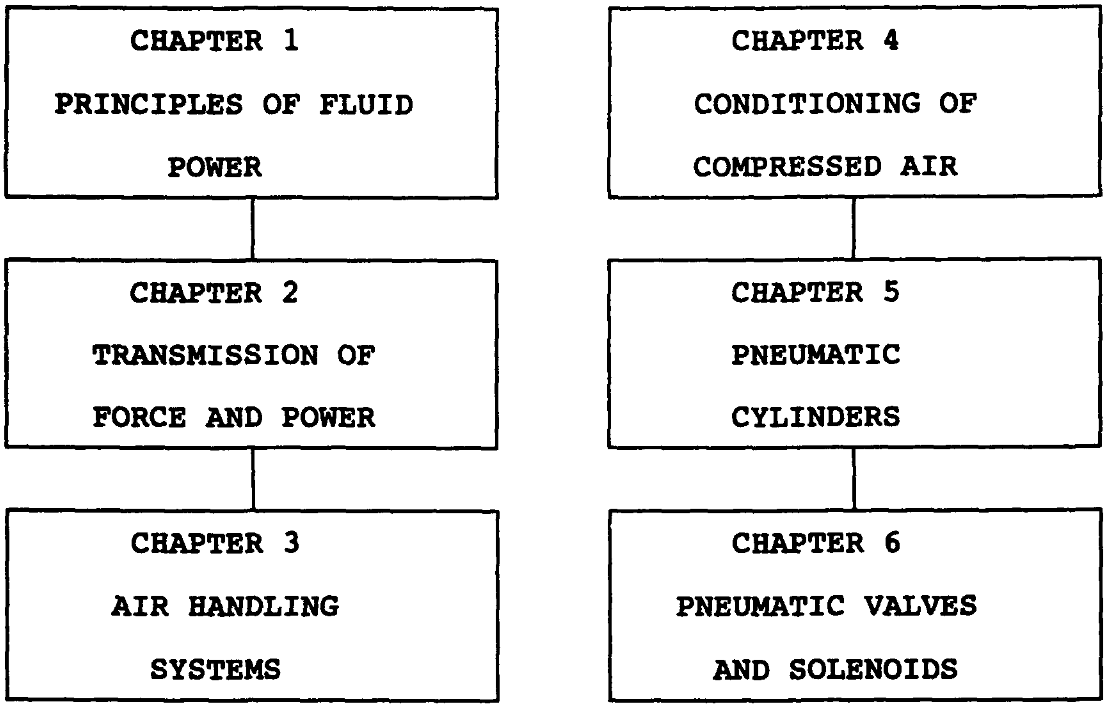


Figure 1. Chapter breakdown of pneumatics course

The objective of chapter one is to have the student understand the physical laws that affect fluid power. The student should also learn the standard terms that are used in describing fluid power systems.

To achieve these objectives, the chapter gives a brief introduction into the purpose of a pneumatic power system. Following this, definitions of pressure and flow are given, as well as the standard units with which these quantities are measured. Finally, the chapter gives a detailed definition of the three physical laws that relate to fluid power systems; Pascal's Law, Boyle's Law and Charles' Law.

After being exposed to the material in chapter two, the student should know how to calculate the forces developed by a pneumatic system and should understand the relationships between force, power, speed and distance within that system. The student should also recognize the types of losses in a pneumatic system (power, speed and distance) and their causes.

Chapter two begins with detailed definitions of force, work and power and how they apply to pneumatic circuits. This is followed by an example explaining how the multiplication of force in a pneumatic system occurs only by sacrificing piston speed and distance traveled. Finally, this chapter covers the losses of power in a system due to fittings and bends in the tubing.

The primary objective of chapter three is to have the student understand how to handle compressed air safely. To achieve this, the principles of lockout/tagout and their applications to pneumatic systems are carefully explained.

Chapter four deals with the conditioning of the compressed air. The student is to learn how and why the air is compressed, cleaned, filtered and lubricated. The student is also expected to understand how the pressure of the compressed air is adjusted and maintained.

To achieve these goals, the chapter details how air is compressed and why the compression is done in stages. This

chapter then discusses the purpose of a Filter-Regulator-Lubricator (FRL) unit. The individual operations of the filter, regulator and lubricator are then discussed in detail.

Chapter five instructs the student on pneumatic cylinders. After completing this chapter, the student should be able to identify the various components of a pneumatic cylinder and should have an understanding of how a cylinder operates. In addition, the student should be able to identify the various types of cylinders and understand in what circumstances they might apply.

The chapter starts with an overview of a basic cylinder and its parts. The chapter then proceeds with a detailed description of the operation of double-acting cylinders. This description continues to cover special cases of double-acting cylinders such as double-end-rod and cushioned cylinders. The chapter ends with a discussion of the two types of single-acting cylinders, normally retracted and normally extended.

The final chapter of the course, chapter six, covers valves and solenoids used in a pneumatic system. After completing this chapter, the student should be able to recognize the various direction and flow control valves used in a pneumatic system. In addition, the student will hopefully know the different types of solenoids used in

industry and what the advantages of each are.

This section addresses these goals by giving the student an in-depth look at pneumatic valves including 2,3,4, and 5-way valves. A final look at solenoids and their applications finishes the lesson plan.

After each chapter, the student is presented with three to six questions. These questions are used to reinforce some of the more important issues covered in each of the chapters.

## CHAPTER II

## COMPUTER-BASED TRAINING

### THE ORIGINS OF CBT

One definition of computer-based training is that it is a method of presenting educational material to a student by way of a computer program. This program provides the opportunity for individual interaction.[5] Computer-based training is known by many titles. These include Computer-Assisted Learning, Computer-Based Instruction, and Computer-Aided Instruction.[1,5,6,7] For the purposes of this study, CBT will be used as the general designation of this learning method.

While it may appear that CBT is a relatively new method of instruction, its development and history actually began in the 1920s. The work of four researchers had a significant impact on the development of CBT. These researchers were; Edward L. Thorndike, Sydney L. Pressey, B. F. Skinner and Norman A. Crowder.[8]

In the 1920s, Pressey, a lecturer at a teachers' college, developed a teaching machine that could produce measurable amounts of learning in students.[9] The machine was a simple multiple-choice testing device. A

question and answer sheet were inserted into a simple wooden box with two levers. The question would appear in a window with the four choices for answers. Students would then select the lever that corresponded to their answer. If the students answered correctly, the next question appeared in the window. If they answered incorrectly, the question remained in the window and an error mark was tallied in a separate window on the box. In this manner, an accurate count of incorrect guesses could be tracked. Pressey is considered to be the originator of hardware (a presentation device or tracking machine).[8]

Shortly after Pressey developed his instructional machine, Edward Thorndike was refining his Law of Effect. This law states that only pleasurable consequences have an effect on the strength of learning. Learning which is accompanied by satisfaction is more likely to be permanent.[10] Since the inception of this theory, studies have shown that while positive reinforcement may have a stronger effect on learning, negative reinforcement cannot be discounted.[10] Despite their findings, Thorndike's work is important as it laid the groundwork for some of the work accomplished by B. F. Skinner.

Skinner, a behavioral psychologist, founded the field of operant conditioning in the early 1950s. The theories of operant conditioning varied dramatically from that of

classical (or Pavlovian) conditioning. Skinner's theory stated that reinforcement cannot follow unless the conditioned response appears; i.e. reinforcement is contingent upon a successful response.[11] Skinner, like Thorndike, found positive reinforcement to be preferable to negative reinforcement. Skinner's work in operant conditioning directly led to his development of the precursor of CBT, programmed learning.

Skinner's form of programmed learning was called a linear program. In this method of instruction, the program would lead a student through a sequence of small steps, asking the student questions after each step. the program was structured in such a way that the probability of the student providing a correct answer was about 95 percent.[8] Once the student answered a question, feedback was immediately provided, reinforcing the student if the answer was right, correcting the student if the answer was wrong. The typical procedure for Skinner's linear program is shown in Figure 2.

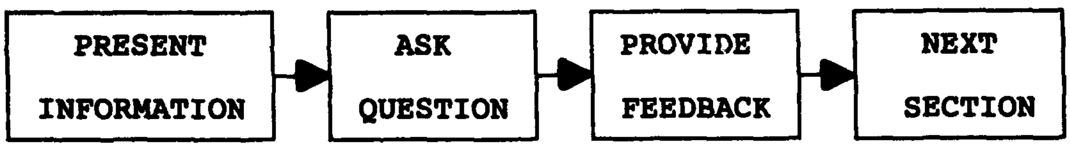


Figure 2. Procedural events in a linear program.

In 1955, Norman Crowder suggested a modification to Skinner's Plan. He called it intrinsic, or branching, programming.[12] With this method, a student is presented with some material to learn, usually a larger amount than that contained in a linear programming section. The student is then asked a multiple-choice question. If the answer to the question is correct, the student moves on to the next section, just as in a linear program. If the answer is incorrect, however, the student is routed to remedial training before being asked a similar question. With this method, students can only move on to the next section after correctly answering the questions at the end of the previous section. The procedural events in an intrinsic program are depicted in Figure 3.

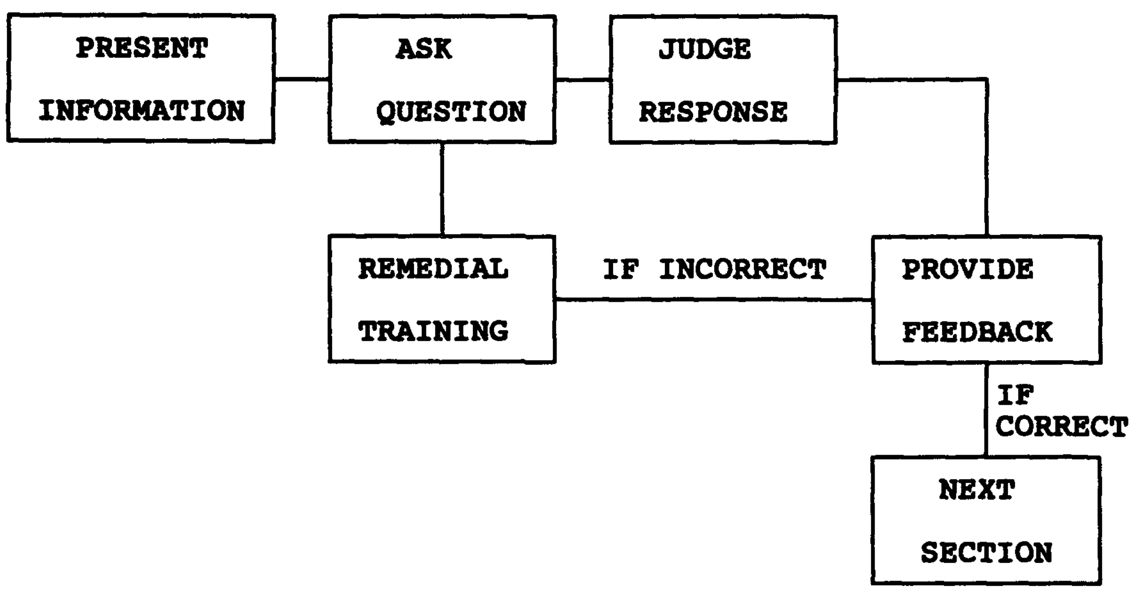


Figure 3. Procedural events in an intrinsic program

## THE EVOLUTION OF CBT

While it is true that Skinner's views significantly shaped CBT in its early years, many researchers have lately changed to an orientation based on the cognitive learning theories.[1] Cognitive learning theories are concerned with the ways individuals gain and use knowledge and not simply with observable events.[13,14] The cognitive learning theory is concerned with several key components. These are: 1) the effects of stimuli on subject's receptors; 2) short-term memory storage; 3) long-term memory storage; 4) the encoding and decoding of information; and 5) the retrieval of stored information.[13]

Robert Gagne has taken the principles of cognitive learning theory and derived several categories of learning outcomes from them. These categories include; verbal information, intellectual skills, cognitive strategies, motor skills and attitudes.[15] Of these five categories, the two which are most likely to be target for CBT are verbal information and intellectual skills.

Verbal information refers to learned material such as names, labels, sentences or other information likely to be printed in text. A performance demonstrating knowledge of this information might be a recitation of Pascal's Law.

Intellectual skills can be sub-divided into four categories that are applicable to CBT. These sub-categories

are; concrete concept, defined concept, rule, and problem solving.

Concrete concept can be stated as identifying objects or properties of objects and events. Demonstrated knowledge of this concept might be identifying a two-way pneumatic valve as normally open or normally closed.

A defined concept is one that must be identified by stating the rule that defines it. The force on a pneumatic piston is a good example of this. To display an understanding of this concept, the student must know the air pressure in the cylinder, the area of the piston and the relationship between them.

A rule is defined as a relation between two or more concepts. Students demonstrate knowledge of a rule when they can apply it to new situations. Using another pneumatics example, if students are given a cylinder area and different air pressure, they should be able to calculate the force. This would demonstrate the application of the "force" rule to a new situation.

Problem solving can be defined as the application of previously learned rules to an unfamiliar situation. Examples of this frequently deal with presenting the student with a "real-life" situation to which he or she must apply the appropriate learned rules.

Once the learning outcomes of a lesson plan have been identified, a sequence of instructional events must be planned to elicit these outcomes. The nine steps of the instructional process are listed below.[16]

1) Gain student's attention.
2) Inform student of lesson objective.
3) Stimulate recall of prior learning.
4) Present stimuli with distinctive features.
5) Guide the student's learning.
6) Elicit performance.
7) Provide feedback.
8) Assess performance.
9) Enhance retention and learning transfer.

It is not always necessary to include all nine steps in an instructional event, though all should be considered when developing the lesson plan. The last two steps, for instance, may be performed off the computer on another media.

A critical aspect in the evolution of CBT is the determination of what gains can be made with its use. Some proposed advantages of CBT over traditional classroom training include:[6,17]

1) CBT is less costly.

2) CBT provides higher quality instruction.

3) CBT takes less time.

4) CBT is more versatile.

5) CBT is preferred by users.

6) CBT helps with administrative aspects (testing, grading, etc.)

While not all of these benefits have been shown to date, several studies have provided some promising results.[13] One finding common in almost all studies shows a reduction in learning time for CBT students.

Students commonly develop a positive attitude toward computers after taking CBT. While not necessarily significant in itself, this benefit may help the student in a future that is certain to contain more computerization.

Most studies also show that CBT either improves learning or, at worst, shows no difference in learning when compared to the traditional classroom approach. While this finding does not greatly strengthen the case for CBT, it certainly shows that CBT is at least as good as the traditional method of teaching.

One benefit that is likely to become more evident is the cost effectiveness of CBT. As hardware prices continue to drop and software packages increase in number, the start-up and maintenance costs of CBT programs should drop.

With all of these demonstrated benefits, it would seem logical to assume that CBT would be in ever growing use throughout the educational systems of the world. However, even today, CBT is most frequently used as a supplement to conventional classroom instruction or as remedial training. One reason for this could be the relative lack of lesson plans available for CBT. Another reason could be the length of time needed to produce a good CBT program (currently approximately 30 - 100 hours for every one hour of instruction).[18] These problems should be reduced as CBT evolves and authoring systems become more "user friendly".

## CHAPTER III

## AUTHORING

### AUTHORWARE

The computer program used to deliver the CBT is a software package called Authorware Professional for Windows. The package is produced by Authorware, Inc. It is an interactive authoring package that allows a programmer to edit, change and even create lesson plans as they are run in real time.

The basic unit of this authoring system is the icon. There are eleven categories of icons, each performing a separate type of function. By arranging these icons in a linear fashion (with several methods of branching allowed) a lesson plan can be developed and implemented.[19]

The Display icon is the most powerful and fundamental icon in the program. This is the icon used whenever text or a graphical display is shown to the user. Display icons contain the actual information that is to imparted to the student.

The Animation icon moves graphical images or text contained in a Display icon to another location in that icon. This presentation of motion enables the student to actually see a described movement rather than merely

visualize it from the verbal description.

The effects of animation on the learner are not widely known. Few studies have been reported investigating the effects of animation as a presentation variable with adults.[20] However, it is believed that many ideas can be understood in a natural way using animation, provided motion is an important attribute of the idea being studied.[21]

The Erase icon deletes previously displayed text or graphics. This allows new information to be displayed on ensuing display icons.

The Wait icon pauses the lesson plan in one of two manners. If the Wait icon is set for a specific amount of time, it will pause in delivering the lesson plan for that time and then resumes without any further input from the student. If the icon is set for user input, a "continue" prompt will appear and the lesson plan is halted until the student chooses to proceed. This is the primary way in which Authorware allows the student to control the pace of the instruction.

The Decision icon allows for numerous branching possibilities within a program. This icon can send the student through a list of topics sequentially or in random order. It can also be used to determine feedback loops and remedial training sections based on the student's assessed learning.

The Interaction icon is a combination of the Display and Decision icons. It provides a display with which a student can interact. The icon then has branching capabilities to respond to the student's input. A good example of this would be a menu display which would allow a student to choose from any one of a number of topics. The branching capabilities would then take the student along the path of the lesson plan for the chosen topic.

The Calculation icon performs programmer written codes and functions. These are particularly useful for tracking data about the student's performance on the lesson. This icon can also be used to "jump" to other files or applications, depending on the user's needs.

The Sound icon allows the programmer to incorporate audio signals into the lesson plan. With the use of specialized digitizers, many sounds can be included into the lesson. This can be particularly helpful when providing feedback.

The Movie icon allows the student to view a series of images placed in rapid succession. This gives the impression of watching a movie or cartoon.

The Video icon allows the student to view video sequences while taking the CBT. The icon is a convenient interface with a video disk player.

The final icon is the Map icon. This icon allows the programmer to group similar icons and lessons. This is a convenience to the instructor only. These icons are transparent to the student.

Examining the structure of a small lesson plan will more clearly illustrate the authoring process. In this example, the student will be presented with a double-acting pneumatic cylinder. The display will then simulate the motion of a cylinder as it is pressurized on one end. The Authorware icon structure for this lesson is shown in Figure 4.

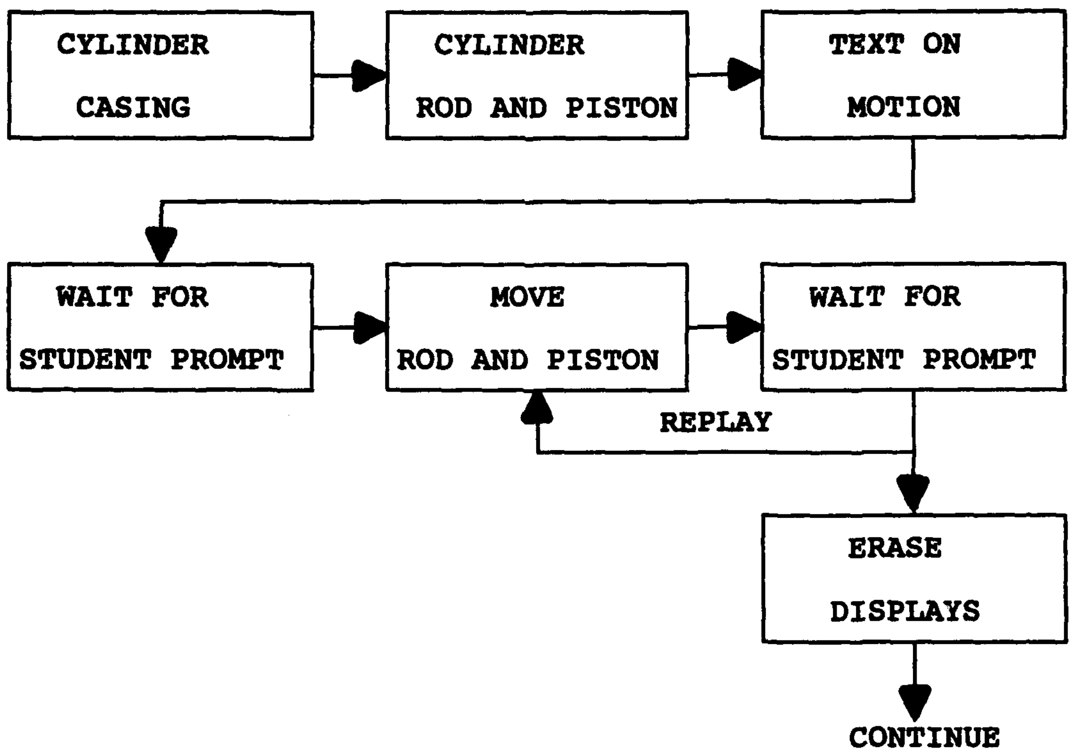


Figure 4. Example icon structure in Authorware

The first two icons present the visual display of a cylinder casing and its rod and piston. The third icon contains text that would explain how and why the piston and rod move in the cylinder. Because the three display icons are placed consecutively, with no intervening icons, all three will appear on one screen to the student.

The Wait icon that directly follows the Display icons ensures the student will have the necessary time to study the screen. Once the student is confident that he/she understands the content of the screen, the "continue" button may be pressed and the lesson will move on.

Once the student activates the continue button, the lesson moves on to the Animation icon. This icon actually causes the piston and rod to move from one end of the cylinder to the other. At this time, another Wait icon permits the student to continue with the lesson or replay the previous animation. This feature again allows the student to control the pace of the program.

When the student elects to proceed onward into the lesson plan, the Erase icon is activated. this icon, or series of icons, erases all unwanted text and displays remaining on the screen. New Display icons can then be inserted into the program, presenting new ideas or concepts.

GUIDELINES FOR AUTHORING

When authoring CBT course material, it is desirable, of course, to avoid making mistakes that might detract from the learning environment. A majority of the most common errors made in CBT material can be grouped into three general categories. These categories, and common errors associated with each, are as follow:[18]

1. Lesson Level
    a) Lesson branches incorrectly.
    b) Inconsistent naming of chapters.
    c) Lessons too big to accomplish in one session.
    d) Too many or too few chapters.
2. Frame Level
    a) Pauses not included for proper student control.
    b) Text and graphics not synchronized properly.
    c) Bad color combinations, making text difficult to read.
    d) Too much text on the frame.
    e) No clear division between text and graphics on a frame.
3. Object Level
    a) Errors in text.
    b) Graphics do not conform to explanations in text.

Avoiding these types of errors is necessary if acceptable training is to be delivered to the student. A preponderance of these errors in a program could lead to frustration on the part of the student and, therefore, a reduction in learning.

A well designed CBT program will avoid these common types of errors and, therefore, prevent unnecessary frustration on the part of the student. Three critical areas to consider when designing the course are: 1) screen design; 2) user control; and 3) assessment feedback.

Good screen design is necessary as the screen is the primary means of interface between the student and the lesson plan. Good screen design incorporates many well known and basic principles of psychology and human factors engineering. These include:[22,23,24]

1) Do not crowd the screen with too much information or text.
2) Avoid the use of scrolling or overlays.
3) Use graphics whenever possible.
4) Use attention capturing devices sparingly.
5) Use different types sizes and styles for emphasis and variety.
6) Use both upper and lower cases in the text.
7) Use titles and headings on all screens.

8) A moving object should be depicted against a fixed background.

Another area crucial to the success of a CBT program hinges on the student's ability to set the pace of the learning. One of CBT's advantages is its ability to adapt to the student's pace. If the student cannot adequately control this, the advantage is lost. Several key principles of designing for user control include:[24]

1) Always allow the student to set the pace.

2) Allow the student to control the sequencing.

3) Use menus as much as possible.

4) Provide multiple (redundant) control options.

The third area to consider when designing the lesson plan is the feedback, or responses, that will be given to the students as they participate in the computer program's tests and evaluations. Two different forms of feedback exist. They are: 1) knowledge of correct response (KCR) feedback and; 2) answer until correct (AUC) feedback.[25]

KCR feedback allows the student only one guess as to the answer. The correct answer is then provided, regardless of the student's response.

AUC feedback allows the student several guesses as to the answer of a question. The student then receives feedback such as "That is incorrect, please try again" until he or she responds correctly to the question.

Very few direct comparisons of the effectiveness of these two forms of feedback have been conducted. Most developers of instructional computer lessons seem to view them as interchangeable.[25] However, there are several guidelines for feedback that should be followed with either (note: some may not apply to KCR). These include[7,24]:

1) Ensure the student makes a response before being shown the answer.
2) Limit the number of tries allowed on each question before presenting the correct answer.
3) Clearly state directions so that errors are unlikely.
4) Use pointing rather than typed input whenever possible
5) Always acknowledge a student's input.
6) Provide corrective feedback for wrong answers.
7) Feedback should be brief and neutral in tone.

# CHAPTER IV

# EXPERIMENTAL DESIGN

## OBJECTIVES OF THE EXPERIMENT

The primary objective of this thesis is to determine if there is a difference in the quality of instruction between computer-based training and the traditional classroom approach. For the purpose of this thesis, quality of instruction is measured by the amount of new information acquired and retained by a student at the completion of the training. Additionally, the research will attempt to determine if there is a significant difference in the amount of time required for the training. Finally it will be determined whether factors such as age or number of years working at the company have any impact on the testing results of the CBT class.

As was previously stated, the lesson plan used for this study is designed to teach students the fundamentals of pneumatics. As both portions, the classroom and the CBT version, were written by this researcher, the two methods consisted of identical material. Most graphs used in the CBT portion were directly scanned from overheads used in the classroom. Text used on the graphics screens was taken directly from the classroom instructor's teaching manual.

The computer-based training differed from the classroom training in two minor ways. First, the questions asked at the end of the chapters were almost entirely multiple-choice. This was done for reasons stated earlier in this thesis. The classroom's questions were all fill-in-the-blank. The instructor could then cover the answers to the questions with the entire class.

The second difference arose from one of the advantages of the CBT. Animation of the graphical displays was used extensively throughout the program. The classroom portion had no animation capabilities.

To clarify this point, Figure 5 depicts an illustration used as an overhead in the classroom training. The figure illustrates that when the smaller piston is moved 4 inches, the larger piston will only move 1 inch. The overhead shows this as one picture. It is up to the students imagination to picture the pistons moving.

The CBT, however, is capable of teaching this concept using animation. The student is shown the piston system in its original state. Then, as the force is applied to the smaller piston, both pistons actually move their appropriate distance.

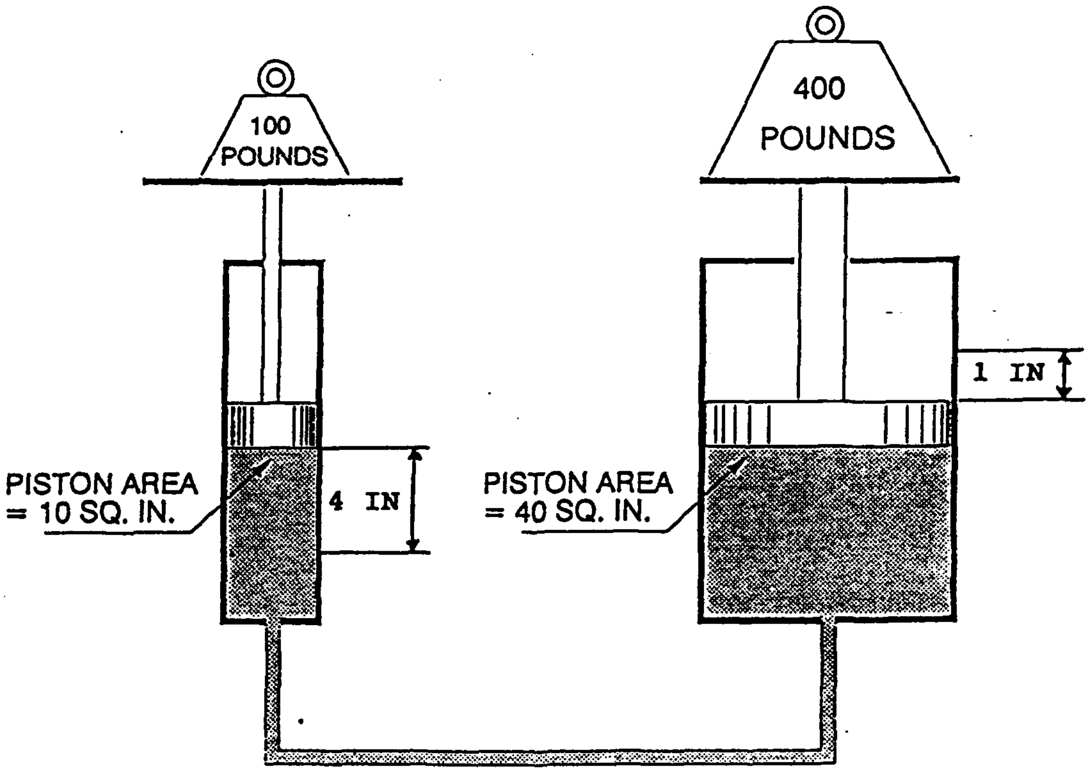


Figure 5. Overhead used for classroom instruction

As the amount of time required to complete the courses was one of the factors being analyzed, the classes were blocked off with ample time to complete the lesson plans. Two four-hour blocks were allotted to each mode of instruction. Both finished well within these prescribed time limits.

The twenty subjects of the experiment were all employees of an automotive manufacturer. Of these twenty participants, ten were randomly selected to participate in the computer-based training class. All subjects were asked to fill out data sheets on themselves which included information about their age, level of education, number of years employed by the company and whether or not they had ever had any pneumatics training. This data is shown in Tables 1 and 2.

Table 1. Recorded data on CBT students

| STUDENT | AGE | LAST YEAR OF SCHOOL COMPLETED | NUMBER OF YEARS AT COMPANY | ANY PRIOR PNEUMATICS TRAINING |
|---|---|---|---|---|
| 1 | 33 | 12 | 9.5 | NO |
| 2 | 23 | 12 | 2.5 | NO |
| 3 | 29 | 12 | 4 | NO |
| 4 | 53 | 12 | 5 | MNX BOOKS |
| 5 | 26 | 12 | 4 | NO |
| 6 | 32 | 12 | 3 | NAVAL COURSE |
| 7 | 27 | 13 | 2.5 | NO |
| 8 | 26 | 16 | 3.5 | NO |
| 9 | 46 | 12 | 3 | NO |
| 10 | 34 | 12 | 3 | NO |

Table 2. Recorded data on classroom students

| STUDENT | AGE | LAST YEAR OF SCHOOL COMPLETED | NUMBER OF YEARS AT COMPANY | ANY PRIOR PNEUMATICS TRAINING |
|---|---|---|---|---|
| 11 | 25 | 12 | 7 | NO |
| 12 | 42 | 13.5 | 3.75 | NO |
| 13 | 44 | 16 | 4 | MNX BOOKS |
| 14 | 24 | 16 | 3 | NO |
| 15 | 38 | 12 | 6.5 | NO |
| 16 | 31 | 12 | 5 | NO |
| 17 | 35 | 14 | 3 | MNX BOOK |
| 18 | 40 | 12 | 5.5 | MNX BOOK |
| 19 | 56 | 12 | 9 | NO |
| 20 | 33 | 12 | 1 | NO |

To be able to ascertain whether or not there is a significant difference in quality between teaching methods, it was first necessary to devise a method of measuring the amount of information acquired by the students. To accomplish this, it was decided that a test would be administered to both groups prior to taking the course. The same test would then be administered after the two groups had completed the course. The difference between the pre-test and post-test scores could then be used to gauge the amount of information acquired and retained by the students at the completion of the course.

To prevent any bias on the part of the grader, it was decided that objective tests would be administered to the students. Objective tests consist of a number of items which have the correct responses all precisely predetermined.[27] Several types of objective tests include multiple-choice, true-false, and matching.

The multiple-choice format was chosen for two reasons. It can be reliably scored, as can all objective tests. It also accomplishes a good job of content sampling, provided enough questions are asked.[26]

A multiple-choice item consisting of any question or incomplete statement is called a step. The various answers available are called options. The correct option is known as the key, while the incorrect options are called

distractors.[27]

When writing the exam items, it was important to follow some basic rules for multiple-choice tests. These rules are used in an attempt to reduce the influence of the student guessing the answer based on the way the question or options are worded. These rules include[26,28] :

1) Use plausible distractors.
2) Keep question length to a minimum.
3) Options should be the same length.
4) Avoid specific determiners in questions and options

The pre/post test used for the assessment consists of 40 multiple choice questions. These questions cover the entire range of the pneumatic lesson plan. Questions were derived from the various class objectives in approximately equal proportions.

One such question was derived from an objective of chapter one of the lesson plan. This objective was to have the students understand the standard terms that are used in describing fluid power systems. The question and options developed from this objective are as follows:

The standard unit of pressure in the U.S. is:

A. Ft-lbs
B. $Lbs/in^2$
C. Lbs
D. Ft-lbs/in

Another question on the pre/post test was developed from an objective of chapter two of the lesson plan. This objective states that the student should know how to calculate the forces developed in a pneumatic system. The question and options are as follows:

What two pieces of information are needed to calculate the force on a cylinder?

A. Air pressure and the length of the cylinder stroke.

B. The power of the cylinder and its length.

C. Air pressure and the area of the cylinder piston.

D. Air pressure and the number of cylinders in the system.

The remainder of the test can be found in Appendix A.

# CHAPTER V

# STATISTICAL TOOLS

## TWO-SAMPLE t-TEST

The primary emphasis of this thesis is to determine if there is any significant difference in instructional quality between traditional classroom training and CBT. In addition, it will be determined whether any difference exists in the time required for the instruction. A two sample t-test is appropriate for both of these analyses.

With large sample sizes, the Central Limit Theorem allows for the use of the sample variance in place of the population variances. With small samples, however, the Central Limit Theorem is no longer valid.[29] To produce a valid test, it is necessary to make stronger assumptions about the underlying populations. These assumptions are:

1) Both populations are normal, and both samples are independent and random.
2) The values of the two population variances are approximately equal.

If these two assumptions are valid, the t-test can be used to compare the means of the two samples.

The t-test can be stated as:

$$T = \frac{(\overline{X} - \overline{Y}) - (u_1 - u_2)}{S_p(1/m + 1/n)^{1/2}} \qquad (5.1)$$

where: $\overline{X}$ = Average of sample 1

$\overline{Y}$ = Average of sample 2

$u_1$= True average of sample 1 population

$u_2$= True average of sample 2 population

m = Number of observations in sample 1

n = Number of observations in sample 2

$S_p$= Pooled estimator of the two sample variances

The null hypothesis for this test is:

$H_o$: $u_1 - u_2 = 0$

This states that there is no difference between the two population means.

The alternate hypotheses are:

$H_a$: $u_1 > u_2$

$H_a$: $u_1 < u_2$

$H_a$: $u_1 \neq u_2$

The rejection regions for these hypotheses can be calculated using the t-statistic at a given alpha level with m+n-2 degrees of freedom. For the previous alternate hypotheses, these are:

| Alternate Hypothesis | Rejection Region |
| --- | --- |
| $H_a$: $u_1 > u_2$ | $T > t_{\alpha,m+n-2}$ |
| $H_a$: $u_1 < u_2$ | $T < -t_{\alpha,m+n-2}$ |
| $H_a$: $u_1 \neq u_2$ | $T > t_{\alpha/2,m+n-2}$ or $T < -t_{\alpha/2,m+n-2}$ |

The pooled estimator of the common variance is merely the weighted average of the two sample variances. It is calculated as follows:

$$S_p^2 = \frac{(m-1)S_1^2 + (n-1)S_2^2}{m+n-2} \qquad (5.2)$$

ONE SAMPLE t-TEST

Because the students in the traditional classroom instruction sample were all trained for the same amount of time, this time can be taken as the standard average. A one sample t-test will be used, therefore, to compare the mean of the CBT class to this standard.

As with the two sample test, the Central Limit Theorem no longer applies to small sample sizes. When $\overline{X}$ is the mean of a random sample of size n from a normal distribution with mean u, the t-test can be defined as follows:

$$T = \frac{\overline{X} - u}{S/(n)^{1/2}} \qquad (5.3)$$

with n-1 degrees of freedom.

The null hypothesis for this test is:

$H_o$: $\overline{X} = u$

The alternate hypotheses and the accompanying rejection regions are:

| <u>Alternate Hypothesis</u> | <u>Rejection Region</u> |
|---|---|
| $H_a$: $\bar{X} > u$ | $T > t_{\alpha,n-1}$ |
| $H_a$: $\bar{X} < u$ | $T < -t_{\alpha,n-1}$ |
| $H_a$: $\bar{X} \neq u$ | $T > t_{\alpha/2,n-1}$ or $T < -t_{\alpha/2,n-1}$ |

CHAPTER VI

# STATISTICAL ANALYSIS

## QUALITY OF INSTRUCTION ANALYSIS

The data required for the various analyses included pre and post-test scores for all twenty students as well as the individual times required to take the CBT training. This data, along with needed averages and variances, can be found in Tables 3 and 4.

Table 3. CBT training data

| STUDENT | PRE-TEST SCORE | POST-TEST SCORE | IMPROVEMENT | TIME TO COMPLETE(MIN) | |
|---|---|---|---|---|---|
| 1 | 27 | 34 | 7 | 127 | |
| 2 | 22 | 31 | 9 | 165 | |
| 3 | 27 | 34 | 7 | 137 | |
| 4 | 19 | 36 | 17 | 360 | |
| 5 | 18 | 23 | 5 | 141 | |
| 6 | 25 | 38 | 13 | 117 | |
| 7 | 25 | 32 | 7 | 115 | |
| 8 | 36 | 39 | 3 | 130 | |
| 9 | 19 | 28 | 9 | 180 | |
| 10 | 30 | 36 | 6 | 120 | |
| | | | 83 | 1592 | SUM |
| | | | 8.3 | 159.2 | AVG |
| | | | 16.46 | 5419.07 | VAR |
| | | | 4.06 | 73.61 | S.D. |

Table 4. Classroom training data

| STUDENT | PRE-TEST SCORE | POST-TEST SCORE | IMPROVEMENT | TIME TO COMPLETE(MIN) | |
|---|---|---|---|---|---|
| 11 | 19 | 26 | 7 | 240 | |
| 12 | 14 | 33 | 19 | 240 | |
| 13 | 23 | 34 | 11 | 240 | |
| 14 | 22 | 28 | 6 | 240 | |
| 15 | 26 | 31 | 5 | 240 | |
| 16 | 21 | 31 | 10 | 240 | |
| 17 | 24 | 36 | 12 | 240 | |
| 18 | 26 | 35 | 9 | 240 | |
| 19 | 23 | 32 | 9 | 240 | |
| 20 | 26 | 34 | 8 | 240 | |
| | | | 96 | 2400 | SUM |
| | | | 9.6 | 240 | AVG |
| | | | 15.6 | 0.00 | VAR |
| | | | 3.95 | 0.00 | S.D. |

As stated earlier, the two sample t-test was the test used to determine if a difference exists between the means of the two samples (CBT and classroom post-test - pre-test). This was accomplished using equation 5.1.

The null hypothesis for this experiment was $\overline{X} = \overline{Y}$. The alternative hypothesis was $\overline{X} \neq \overline{Y}$. The pooled estimator of the common variance was found using equation 5.2. The results of the calculations are as follows:

$$S_p^2 = \frac{(10-1)16.46 + (10-1)15.6}{10 + 10 - 2} = 16.03$$

$$S_p = (16.03)^{1/2} = 4.00$$

$$T = \frac{9.6 - 8.3}{4.0(1/10 + 1/10)^{1/2}} = .73$$

For $H_a$: $\bar{X} \neq \bar{Y}$, a two-tailed test is required. The region for this test using a 95% confidence level is:

$$T > t_{.025,18} \quad \text{or} \quad T < -t_{.025,18}$$

From a t-distribution chart, we can find that:

$$t_{.025,18} = 2.101$$

Because T = .73 is less than 2.101, the null hypothesis is not rejected. It cannot, therefore, be determined that there is any difference in the quality of instruction between CBT and traditional classroom training.

TIME ANALYSIS

A standard one sample t-test was accomplished using equation 5.3 to determine if there was a difference in the time required to acquire the information between CBT and classroom training. The 240 minute classroom time was used as the standard against which the CBT was measured.

The null hypothesis ($H_0$) was that the average time for the CBT was the same as the standard time: $H_0$: $\bar{X}$ = 240 min. The alternate hypothesis ($H_a$) was that the time for the CBT was less than 240 minutes: $H_a$: $\bar{X}$ < 240 min.

The t-test was run at the 95% confidence level. The data for this test can also be found in Tables 3 and 4.

$$T = \frac{159.2 - 240}{(73.61)/(10)^{1/2}} = -3.47$$

and $t_{.05,9} = -1.83$

Because $-3.47 < -1.83$, the null hypothesis can be rejected. We can conclude, therefore, that the average time to aquire information is significantly lower for CBT.

*LEARNING EFFICIENCY*

With no difference in the quality of learning, but a difference in time required to acquire information, a question begs to be asked: Is there a difference in the efficiency of information gain between CBT and traditional classroom learning?

To ascertain this, the efficiency of the two methods was calculated into a figure representing the average minutes of training per question improved. This data can be found in Tables 5 and 6.

Table 5. CBT training efficiency data

| STUDENT | IMPROVEMENT | TIME | EFFICIENCY | |
|---|---|---|---|---|
| 1 | 7 | 127 | 18.14 | |
| 2 | 9 | 165 | 18.33 | |
| 3 | 7 | 137 | 19.57 | |
| 4 | 17 | 360 | 21.18 | |
| 5 | 5 | 141 | 28.20 | |
| 6 | 13 | 117 | 9.00 | |
| 7 | 7 | 115 | 16.43 | |
| 8 | 3 | 130 | 43.33 | |
| 9 | 9 | 180 | 20.00 | |
| 10 | 6 | 120 | 20.00 | |
| | | | 214.19 | SUM |
| | | | 21.42 | AVG |
| | | | 81.44 | VAR |
| | | | 9.02 | SD |

Table 6. Classroom training efficiency data

| STUDENT | IMPROVEMENT | TIME | EFFICIENCY | |
|---|---|---|---|---|
| 11 | 7 | 240 | 34.29 | |
| 12 | 19 | 240 | 12.63 | |
| 13 | 11 | 240 | 21.82 | |
| 14 | 6 | 240 | 40.00 | |
| 15 | 5 | 240 | 48.00 | |
| 16 | 10 | 240 | 24.00 | |
| 17 | 12 | 240 | 20.00 | |
| 18 | 9 | 240 | 26.67 | |
| 19 | 9 | 240 | 26.67 | |
| 20 | 8 | 240 | 30.00 | |
| | | | 284.07 | SUM |
| | | | 28.41 | AVG |
| | | | 104.87 | VAR |
| | | | 10.24 | SD |

The previously used two sample t-test was used to compare the two means. The calculations are shown below:

$$S_p^2 = \frac{(9)(81.44) + (9)(104.87)}{18} = 93.15$$

$$S = 9.65$$

$$T = \frac{21.42 - 28.41}{(9.65)(1/5)^{1/2}} = -1.61$$

$$t_{.025,18} = -2.101$$

Because -1.61 > -2.101 the null hypothesis cannot be rejected. Therefore, we cannot conclude that there is any significant difference in learning efficiency between the two teaching methods.

REGRESSION ANALYSES

In addition to the comparative analyses, regression analyses were run on the CBT sample to determine if factors such as age or number of years with the company affect the amount of information acquired and retained by the students.

Single linear regressions were run using the improvement in test scores as the dependent variable. The independent variable were the age of the students and the number of years they had worked at the company. This data

can be found in Table 7.

Table 7. Data used for regression analyses on CBT students

| STUDENT | IMPROVEMENT | AGE | YEARS WITH COMPANY |
|---|---|---|---|
| 1 | 7 | 33 | 9.5 |
| 2 | 9 | 23 | 2.5 |
| 3 | 7 | 29 | 4 |
| 4 | 17 | 53 | 5 |
| 5 | 5 | 26 | 4 |
| 6 | 13 | 32 | 3 |
| 7 | 7 | 27 | 2.5 |
| 8 | 3 | 26 | 3.5 |
| 9 | 9 | 46 | 3 |
| 10 | 6 | 34 | 3 |

The two simple linear regression analyses did not reveal a correlation between the two independent variables and the dependent variable. The results of the regressions are shown below:

<u>Age vs Improvement</u>

X Coefficient: .295

Constant: -1.41

Coefficient of correlation: .695

<u>Years with company vs Improvement</u>

X Coefficient: .051

Constant: 8.1

Coefficient of correlation: .025

The coefficients of correlation in both regressions do not support the theory that a strong linear relationship

exists between either independent variables and the dependent variables.

## CHAPTER VII

## CONCLUSIONS

The primary objective of this research was to determine if there is a difference in the quality of training between CBT and conventional classroom training. The difference in time required for instruction was also analyzed. Finally, some regression analyses were run to determine if there was a strong correlation between age or time employed and information acquisition.

The statistical test run on the quality of training parameter showed no significant quality difference existed between the two types of training. The CBT proved to be equally effective at training technical personnel on basic pneumatics as the classroom approach.

The statistical test run on the time required to acquire this knowledge did reveal a difference between the two methods, however. The CBT did show a significant decrease in the amount of time required to learn the material.

The regression analyses did not show any significant correlation between the quality of learning and the two factors of age and number of years employed by the company.

Perhaps, with more experimentation, enough data could be gathered to provide some insight in these areas.

Because CBT proved to be as effective and quicker than the conventional classroom approach, an economic justification for CBT can be considered. If a company can place some numeric values on a number of variables, a determination of when to use CBT can be ascertained. The breakeven point with the classroom approach can be based on the number of students required to take a course.

The two cost equations are as follows:

Cost of classroom approach ($)

$$N(C_w)(H_c) + N(C_s) + C_d(HDEV_c) + C_t(HDEV_c)(N/n) \qquad (7.1)$$

Cost of CBT approach ($)

$$N(C_w)(H_b) + N[(H_b/H)(AC_h + AC_s)] + HDEV_b(C_d) \qquad (7.2)$$

where: N = Number of students taking the course per year

n = Number of students per classroom session

$C_w$= Cost of wages per hour for students

$C_t$= Cost of wages per hour for classroom instructor

$C_d$= Cost of wages per hour for course developer

$C_s$= Cost of classroom material per student

$AC_h$= Amoritized cost of CBT hardware

$AC_s$= Amoritized cost of CBT software

$H_c$= Class hours needed to complete course

$H_b$ = Computer hours needed to complete course

$HDEV_c$ = Hours needed to develop classroom course

$HDEV_b$ = Hours needed to develop CBT course

H = Total hours available per year for instruction

Setting equations 7.1 and 7.2 equal to each other and solving for the number of students results in:

$$N = C_d(HDEV_c - HDEV_b)/[C_w(H_b - H_c) + (H_b/H)(AC_h + AC_s) - C_s - C_t(H_c)/n \qquad (7.3)$$

By using equation 7.3, an employer can determine at which point it would become economically desirable to use CBT. Typically, for small numbers of students the hardware and software costs are going to offset any potential gain. However, for a greater number of students or for classes that must be repeated often, CBT can provide an economical solution.

Finally, the possible advantages of CBT can be critically analyzed using the results obtained from this study. The difference in quality of instruction and the economic benefits have been covered in detail. Also CBT was shown to take less time than the conventional classroom approach.

The versatility of CBT was demonstrated by the use of animation in the pneumatic course. Static displays as well as displays showing motion can easily be incorporated into the lesson plan. With the ability to include sound and interactive video, CBT possesses expansive capabilities.

The administrative uses of CBT became evident after the data was collected for this study. With the proper use of the software and a data base, tasks such as testing, grading and tracking student progress can be handled efficiently.

To determine if the CBT was preferred by the students, an informal questionnaire was given to each of the students at the end of the course. All students participating in the stated they enjoyed the CBT. Over fifty percent specifically stated that they preferred the CBT to the conventional classroom approach. These responses, albeit from a small sample, are encouraging.

Further research into the possibilities of CBT is required. As computer software becomes more refined, the uses and applications are CBT are bound to increase. More data is needed to determine for which of these uses CBT can most effectively be applied.

APPENDIX

PNEUMATIC COURSE PRE/POST TEST

PNEUMATICS COURSE PRE-ASSESSMENT

1. If the surface area of a cylinder under constant pressure is <u>increased</u>, will the force produced by the cylinder increase, decrease or remain the same.

   A. Increase
   B. Decrease
   C. Remain the same

2. The standard unit of pressure in the U.S. is:

   A. Ft-lbs
   B. Lbs/$in^2$
   C. Lbs
   D. Ft-lbs/in

3. Figure 1 is a:

   A. 2-way normally closed valve
   B. 3-way normally closed valve
   C. 3-way normally open valve
   D. 2-way normally open valve

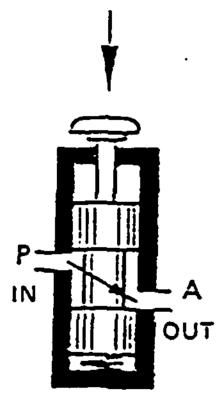


FIGURE 1

4. What are cushioned cylinders used for?

   A. Reduce cylinder vibration
   B. Reduce impact to the cylinder
   C. Decelerate delicate loads slowly
   D. B and C

5. Gauge pressure readings are ___________ absolute pressure readings.

A. 14.7 PSI less than
B. 14.7 PSI more than
C. the same as
D. 90 PSI more than

6. If a closed center 4-way valve is actuated to the center position, the pressurized air is:

A. Vented to the atmosphere
B. Blocked from entering the cylinder or being vented
C. Directed into the rod end port of the cylinder
D. Directed into the blind end port of the cylinder

7. Figure 2 is a:

A. Double-acting cylinder
B. Push type single-acting cylinder
C. Cushioned cylinder
D. Pull type single-acting cylinder

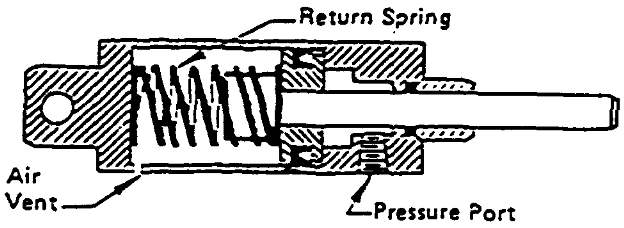


FIGURE 2

8. It is always desirable to have a lubricator in a pneumatic system.

A. True
B. False
C. It makes little difference whether a lubricator is present or not

9. The standard unit of air flow in the U.S. is:

   A. PSI
   B. SCFM
   C. BTU
   D. Horsepower

10. Three basic categories of pneumatic control valves are:

   A. Speed, pressure and vibrational
   B. Force, flow and vibrational
   C. Distance, pressure and flow
   D. Flow, pressure and directional

11. Figure 3 is a(n):

   A. Regulator
   B. Pilot-operated solenoid
   C. In-line valve
   D. Direct-acting solenoid

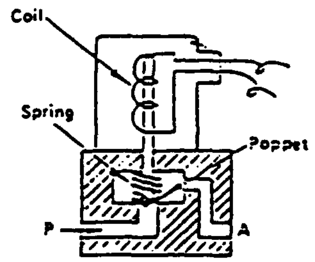


FIGURE 3

12. A double-acting cylinder cannot operate properly if it is fed pressurized air by a 3-way valve.

   A. True
   B. False

13. In Figure 4, how much force will piston 2 support?

   A. 400 lbs
   B. 200 lbs
   C. 40 lbs
   D. 100 lbs

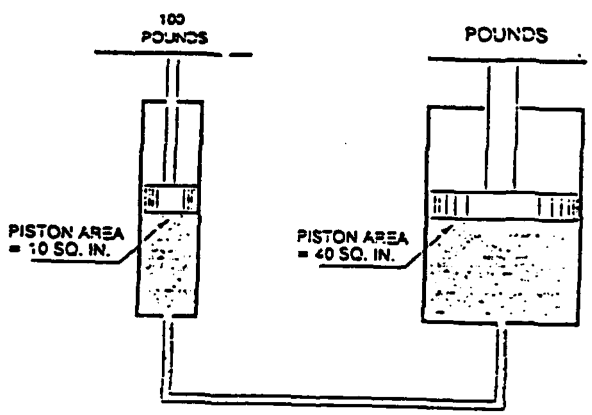


FIGURE 4

14. What component of a pneumatic system removes dirt and water from the system?

A. Solenoid
B. Regulator
C. Compressor
D. Filter

15. The valve that shuts off the air from the main supply must be of the type that can be locked in ____ position, following standard Lockout/Tagout procedures.

A. the on
B. the off
C. Either the on or off

16. Because air acts according to this law, pneumatic circuits can be used to transfer force from one point to another.

A. Charles' Law
B. Newton's Law
C. Boyle's Law
D. Pascal's Law

17. Figure 5 is a:

A. 3-way normally open valve
B. 3-way normally closed valve
C. 4-way valve
D. 2-way normally closed valve

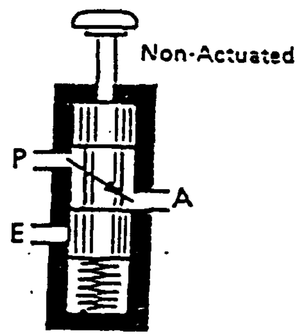


FIGURE 5

18. What is the purpose of a pneumatic power system?

    A. To transfer power from one point to another using pressurized air
    B. To provide pressurized air for air conditioning systems
    C. To provide cooling air for electronic equipment.
    D. To provide electrical power for air cylinders.

19. How do fittings and bends in a pneumatic system cause a loss of energy to the system?

    A. They increase the distance traveled by the air
    B. They cause turbulence
    C. They cause vibrations in the tubing and piping
    D. They permit small air leaks at the joints

20. What two pieces of information are needed to calculate the force on a cylinder?

    A. Air pressure and the length of the cylinder stroke.
    B. The power of the cylinder and its length
    C. Air pressure and the area of the cylinder piston
    D. Air pressure and the number of cylinders in the system

21. Why must air be compressed in stages?

    A. To remove more impurities and reduce compressor size
    B. To prevent the softening of tubing joints due to the hot air
    C. To reduce the pressure to an acceptable level for the pneumatic equipment
    D. To prevent excessive heat and to increase efficiency

22. What are the components of a <u>duo</u> unit?

    A. Compressor and filter
    B. Regulator and lubricator
    C. Filter and regulator
    D. Compressor and cylinder

23. Figure 6 is a:

A. Cushioned cylinder
B. Single-acting cylinder
C. Double-end-rod cylinder
D. A and B

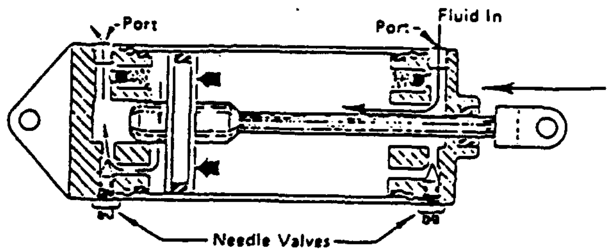


FIGURE 6

24. What is an advantage of a pilot-operated solenoid over a direct-acting solenoid?

A. Operates over a greater range of pressures
B. Quieter
C. Can control pressure surges from the air distribution system
D. All of the above

25. What type of 2 and 3-way valves allow air to pass in the non-actuated state?

A. Normally open
B. Normally closed
C. Float center
D. Closed center

26. If the surface area of a cylinder under constant pressure is increased, what two measures of cylinder performance will decrease?

A. Work and speed
B. Force and power
C. Work and force
D. Speed and distance traveled

27. A regulator __________ the air pressure coming in from the air distribution system.

 A. Increases
 B. Decreases
 C. Has no effect on

28. A double-end-rod cylinder:

 A. Has air ports on both ends of the cylinder
 B. Has a piston rod that extends through both ends of the cylinder
 C. Can accomplish work on both strokes of the cylinder rod
 D. All of the above

29. In Figure 7, how far will piston 2 move if piston 1 moves 4 inches.

 A. 4 inches
 B. 16 inches
 C. 1 inch
 D. 0 inches

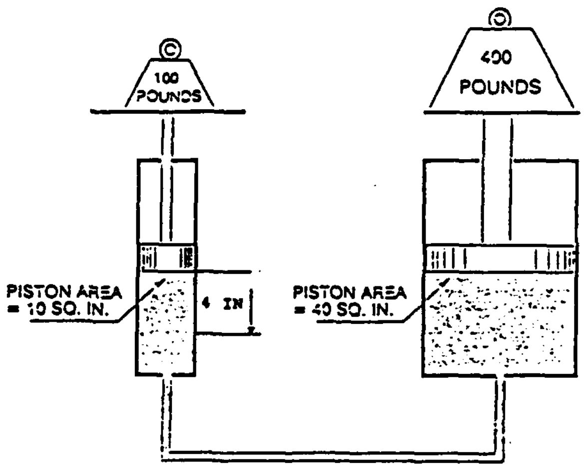


FIGURE 7

30. The designation of "2-way", "3-way" etc on control valves refers to:

A. The number of positions the valve can be placed in
B. The number of cylinders connected to the valve
C. The number of air porting connections
D. None of the above

31. In a pneumatic system, pressure losses of greater than ______ are considered excessive.

A. 1%
B. 3%
C. 5%
D. 10%

32. What are the three components of a trio unit?

A. Regulator, compressor and filter
B. Shut-off valve, compressor and cylinder
C. Filter, regulator and lubricator
D. Compressor, filter and lubricator

33. Air should always be conditioned by a trio unit before it is compressed.

A. True
B. False

34. Figure 8 is a:

A. Closed center 4-way valve
B. Float center 4-way valve
C. Normally open 3-way valve
D. Normally closed 3-way valve

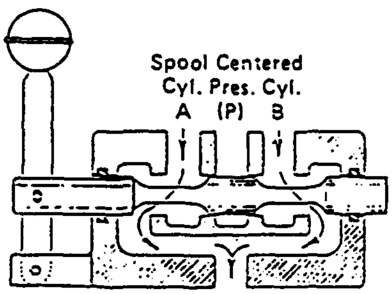


FIGURE 8

35. What pneumatic component prevents an excess buildup of pressure in a pneumatic circuit?

    A. Regulator
    B. Solenoid
    C. 3-way normally open valve
    D. 2-way normally open valve

36. What are the two basic types of cylinders?

    A. Single-end-rod and double-end-rod
    B. Spring return and manual return
    C. Single-acting and double-acting
    D. Cushioned and non-cushioned

37. Figure 9 is a:

    A. Double-acting cylinder
    B. Single-acting cylinder
    C. Double-end-rod cylinder
    D. Cushioned cylinder

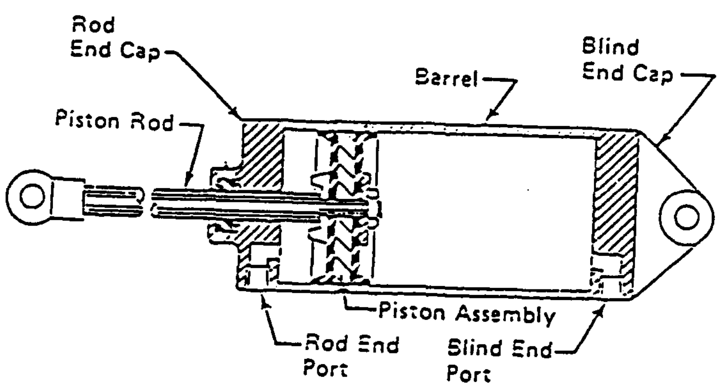


FIGURE 9

38. A 5-way valve has:

A. 1 pressure port
B. 2 pressure ports
C. 3 pressure ports
D. 4 pressure ports

39. A single-acting cylinder is returned to its home position by:

A. A spring
B. Pressurized air
C. An operator
D. Gravity

40. Which port is being pressurized when a double-acting cylinder is extending?

A. Valve port
B. Vent port
C. Rod-end port
D. Blind-end port

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